Section 1.0 Introduction

Acid mine drainage has been produced by coal mining operations in the Appalachian Coal Region of the eastern United States and elsewhere for many years, resulting in extensive surface-water and ground-water pollution. The Federal Clean Water Act (CWA), the Federal Surface Mining Control and Reclamation Act (SMCRA), and associated state laws require coal mine operators to take steps to prevent or control the production of acid mine drainage, and to treat acid mine drainage from active and reclaimed surface mining operations so that point-source discharges meet the applicable effluent limitations found at 40 CFR part 434.

Much of the acid mine drainage occurring in the Appalachian Coal Region is emanating from abandoned surface and underground mines that were mined and abandoned prior to the enactment of SMCRA and the CWA. According to the Appalachian Regional Commission (1969), 78 percent of the acid mine drainage produced in northern Appalachia is associated with inactive or abandoned mines. More recent U.S. Geological Survey reports (Wetzel and Hoffman, 1983, 1989) provide summaries of surface-water quality data and patterns of acid mine drainage problems throughout the Appalachian Coal Basin. A set of companion reports (Hoffman and Wetzel, 1983, 1989) contain similar information for the Interior Coal Province of the Eastern Coal Region of the United States. Current EPA data document that the number one water quality problem in Appalachia is drainage from abandoned coal mines, resulting in over 9,700 miles of acid mine drainage polluted streams. A 1995 EPA Region III survey found that 5,100 miles of streams in four Appalachian states are impacted by acid mine drainage, predominantly from abandoned coal mines. Pennsylvania alone accounts for approximately 2,600 acid mine drainage impacted stream miles.

The remaining coal reserves in these abandoned mine land areas frequently make them attractive for the active mining industry; but traditionally, potential liability for the treatment of the abandoned mine drainage established a disincentive to the permitting and remining of these areas. If a pre-existing pollutional discharge of acid mine drainage was occurring within the area or on an area hydrologically connected to the permit area, mine operators often faced liability to treat the discharge to best available technology economically achievable (BAT) effluent standards (40 CFR part 434).

1.1 Remining Program History

In the 1980s, changes to the CWA (see 1987 Amendment to Section 301; the Rahall Amendment) and state mining laws (e.g., 1984 Amendment to the Pennsylvania Surface Mining Conservation and Reclamation Act (PA SMCRA)) provided incentives to mine operators to remine areas with pre-existing pollutional discharges. Pursuant to these changes in state and federal laws, the flow and water quality characteristics or "baseline pollution load" of these pre-existing discharges must be documented prior to the commencement of the remining operation. Under this program, the mine operator submits a surface mining permit application including: (1) sufficient baseline pollution load data, and (2) a pollution abatement plan which demonstrates how the remining operation proposes to eliminate or reduce the pre-existing pollution. The regulatory authority completes a "best professional judgement (BPJ) analysis" pursuant to Section 402(a) of the CWA as part of the permit review process. A BPJ-based remining permit may be issued that requires the mine operator to treat the pre-existing discharges only if the baseline pollution load has been exceeded, and then only treat the discharges to baseline pollution load levels rather than to conventional BAT effluent standards. The procedures to determine the level of treatment required to meet baseline is not standard, and is dependent on various site-specific elements of the BPJ.

BPJ is defined as: "The highest quality technical opinion forming the basis for the terms and conditions of the treatment level required after consideration of all reasonably available and pertinent data. The treatment levels shall be established in accordance with Sections 301 and 402 of the Federal Water Pollution Control Act (33 USC §§1311 and 1342)." BPJ-determined effluent limits must be based upon BAT or any more stringent limitation necessary to ensure the discharge does not violate state in-stream water quality standards. Theoretically, BPJ-determined treatment levels can range from the pre-existing baseline level to the conventional BAT limits.

The BPJ analysis is a BAT analysis in miniature, specific to an individual mine site, rather than an entire class of industrial wastewater discharges (i.e., surface coal mining). For a remining permit, the analysis should consider the cost of treatment to conventional surface mining BAT levels, as well as the cost of achieving pollution load reduction through the implementation of a pollution abatement plan. The permit writer also should consider any unique factors pertaining to the proposed remining operations and any potential adverse or beneficial non-water quality environmental impacts.

The Rahall Amendment to the Federal Clean Water Act in 1987 provided a foundation for the development of effective remining programs in many coal mining states. Between 1984 and 1988, EPA and the Commonwealth of Pennsylvania Department of Environmental Protection (PADEP) cooperated in a remining project. The purpose of that project was to develop an effective remining program pursuant to the 1984 Amendments to PA SMCRA, that would not be in conflict with the provisions of the Federal Clean Water Act and the associated 40 CFR part 434 regulations. Pennsylvania promulgated remining regulations on June 29, 1985, that were approved by the U.S. Office of Surface Mining Reclamation and Enforcement (OSMRE) on February 19, 1986.

The work products of the PADEP/EPA cooperative study included preliminary treatment costing and remining costing studies in 1986 (prepared by Kohlmann Ruggiero Engineers (KRE), and Phelps and Thomas of the Pennsylvania State University), the development of the REMINE computer software package and Users Manual in 1987, and associated technical reports in 1987 and 1988. Included in these technical reports was the final treatment costing study (Kohlmann Ruggiero Engineers, P.C., 1988) and a series of eight water quality statistical reports prepared by Dr. J. C. Griffiths of the Pennsylvania State University. Since these unpublished statistical analyses of mine drainage datasets are relevant to baseline pollution load statistics, they are presented in an abridged form in a companion volume to this report, prepared by US EPA (2001; EPA-821-B-01-014).

1.2 Pennsylvania DEP Remining Permitting Procedures

Since 1985, PADEP has issued approximately 300 remining permits, with a 98 percent success rate. A successful remining site is one that has been mined without incurring treatment liability as the result of exceeding the baseline pollution load of the pre-existing discharges. Data from 112 of these sites that have been completely reclaimed have been used by EPA in evaluating Best Management Practice (BMP) performance (see EPA Coal Remining BMP Guidance Manual). The elements of establishing baseline pollution loads and measuring compliance that are provided in the Pennsylvania program guidance on the BPJ process are summarized below.

1.2.1 Pre-existing Discharges

Various relationships exist between the permit boundaries of surface coal mine sites and the location of pre-existing pollutional discharges. The simplest relationship exists where a single abandoned mine drainage discharge point is located within, or closely adjacent to, the proposed surface mine permit boundaries, and the proposed mine is the only active mining operation. A more complex relationship occurs where numerous pre-existing discharges from the same coal seam, or from multiple coal seams, are located within the proposed surface mine permit area or are hydrologically connected to that permit area. In addition, there are situations where more than one active mining operation is hydrologically connected to the same pre-existing discharge. The PADEP program includes considerations for: (a) monitoring and baseline data collection of single and multiple discharges, (b) establishing baseline pollution load of single or multiple discharges through statistical methods, and (c) determining compliance with BPJ determined effluent limits for the pre-existing discharges through statistical methods and permit conditions (for individual operators and multiple operators).

In many cases, pre-existing pollutional discharges may occur in the form of numerous discharge points, all of which emanate from a hydrologically discrete ground-water flow system. Ground-water flow paths may change during and following remining such that new discharge points appear, former discharge points disappear, and/or the distribution of flow rates between discharges changes. Where this situation is likely to occur, it is usually advantageous to designate hydrologic units. Each unit must be a hydrologically discrete area such that ground water from one hydrologic unit does not flow to a different hydrologic unit. Hydrologic unit boundaries must be determined for situations where two or more discharges are to be aggregated for load calculations.

Discharges may be combined either naturally or by man-made controls to a single monitoring point, provided that the combination of discharges does not affect the pollution load measurement and that discharges from different hydrologic units are not combined. It is usually desirable (in terms of cost to the operator, permit writing, and compliance monitoring) for the permit applicant to minimize the number of monitoring points needed.

The permit applicant must perform a baseline pollution load statistical determination for each monitoring point. Where multi-discharge hydrologic units are defined, the baseline statistics should be calculated for the aggregate pollution load from the hydrologic unit. That is, loads are summed for all the discharges in the hydrologic unit on a given date. Baseline pollution load determination of a hydrologic unit requires sampling and analysis of each discharge on the same date using an equal number of samples from each discharge. The baseline pollution load is then reported as the combined pollution load from the hydrologic unit.

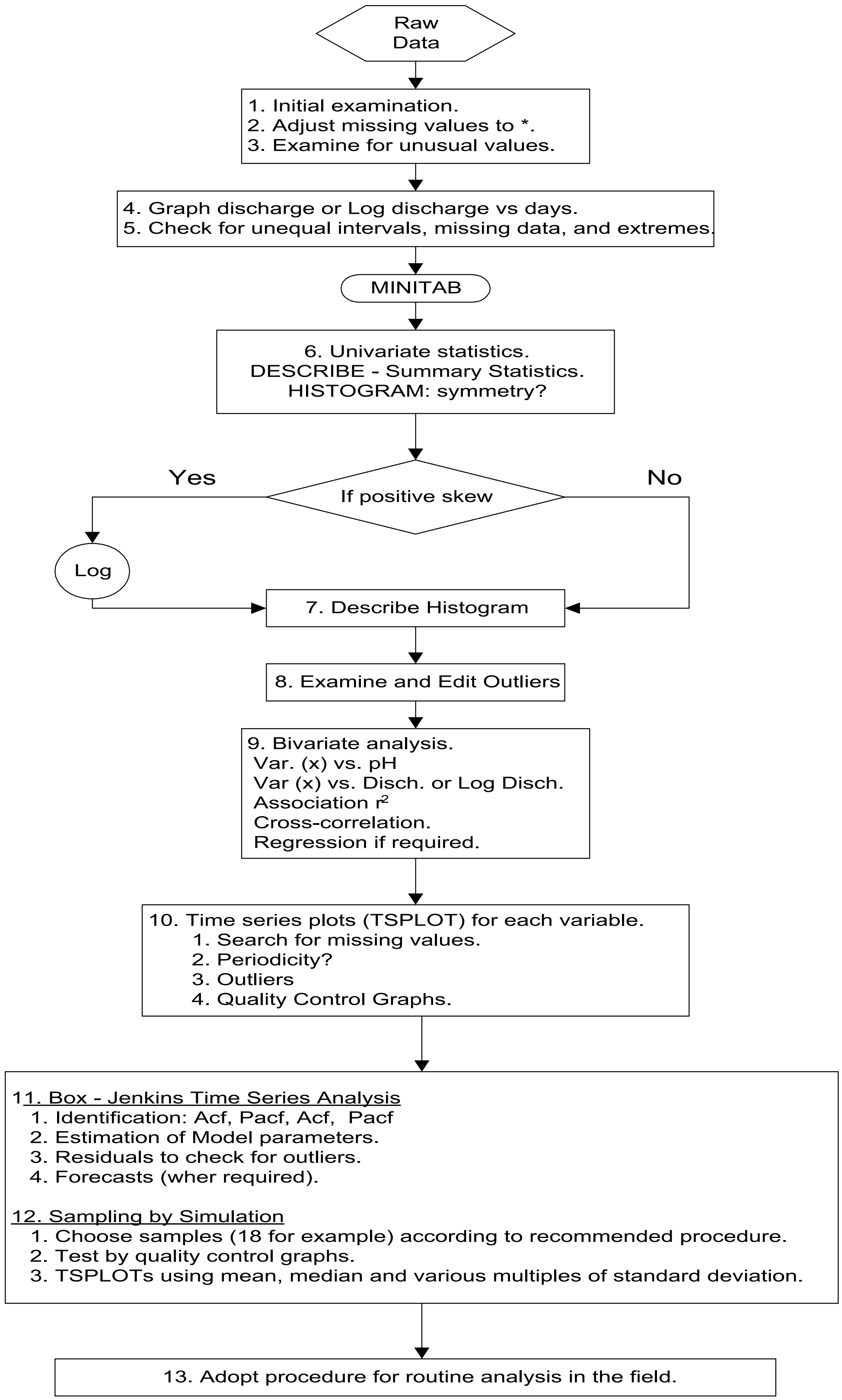
1.2.2 Baseline Pollution Load - Determination and Compliance Monitoring

The process of establishing a realistic baseline pollution load for a mine site requires knowledge of hydrology and statistics. An adequate number of samples must be collected at sufficient time intervals to represent seasonal variations throughout the water year (October through September). The statistical components of establishing baseline pollution load include characterizing the patterns of variation and measuring central tendency, so that any mining-induced changes in pollution load can be distinguished from seasonal and random variations. During active mining and post-mining, individual sampling events and the statistical summary of data collected over successive water years are compared to the pre-mining baseline statistics.

An algorithm for the statistical analysis of mine drainage discharge data was developed by Griffiths (1987) for use in the Pennsylvania program and elsewhere (Figure 1.2a). The algorithm included a simple quality control approach using the exploratory data analysis methods developed by Tukey (1977), and used bivariate statistical methods and time series analyses, where appropriate (e.g., research purposes documented in eight statistical reports by Griffiths, 1987 and 1988). In practice, almost all of the remining permits issued under the Pennsylvania program have used the Baseline Pollution Load Statistical Results Summary presented in Table 1.2a. The five statistical calculations (range, median, quartiles, 95 percent confidence interval about the median, and 95 percent tolerance interval) are based upon Tukey's exploratory data analysis methods and order statistics. Alternative statistical calculations may be used in place of the calculations identified on Table 1.2a, provided that the permit applicant demonstrates that the alternative calculations are statistically valid and applicable. For example, the mean and variance may be used if the data are normally distributed. The REMINE computer software package developed by EPA, PADEP and the Pennsylvania State University was integrated with the MINITAB statistical software package[1], which includes statistical and graphical methods to perform all of the steps in the algorithm presented in Figure 1.2a.

[1]MINITAB is a commercial software package from Minitab, Inc., © 1986, 3081 Enterprise Drive, State College, PA 16801

Figure 1.2a: Algorithm for Analysis of Mine Drainage Discharge Data



While the permit applicant is responsible for submitting the baseline pollution load data and statistical summary, the permit reviewer must check the calculations to ensure that the results are correct. In addition, the reviewer must examine the distribution of the data to determine whether a logarithmic transformation is appropriate. If logarithmic transformation results in a more normal distribution curve, log-transformed data should be used in determining the baseline.

Each discharge point or hydrologic unit will have a baseline pollution load summary. Compliance of discharge points is determined by comparing monthly sample analysis results to the determined baseline pollution load. A discharge point is considered to be in compliance as long as the sample analysis indicates that the pollution load does not exceed either the 95 percent tolerance limit (item 4, Table 1.2a) or the 95 percent confidence interval about the median (item 5, Table 1.2a). The confidence intervals around the median are calculated using the equation noted in Table 1.2a, and taken from McGill, Tukey, and Larsen (1978).

Table 1.2a: Baseline Pollution Load Summary

Mine ID: ______ Mine Name: ___________________________ Hydrologic Unit ID:_____

# of Samples:____		Flow	Loading in Pounds Per Day				
Statistical Results		**(gpm)**	**Acidity**	**Iron**	**Manganese**	**Aluminum**	**Sulfates**
1. Range	Low:						
	High:						
2. Median							
3. Quartiles	Low:						
	High:						
4. Approximate 95%	Low:						
tolerance limits	High:						
5. 95% Confidence Int.	Low:						
about median*	High:						

***Note:** Confidence intervals about median = M +/- 1.58[1.25R/(1.35xSQR(N)] where:

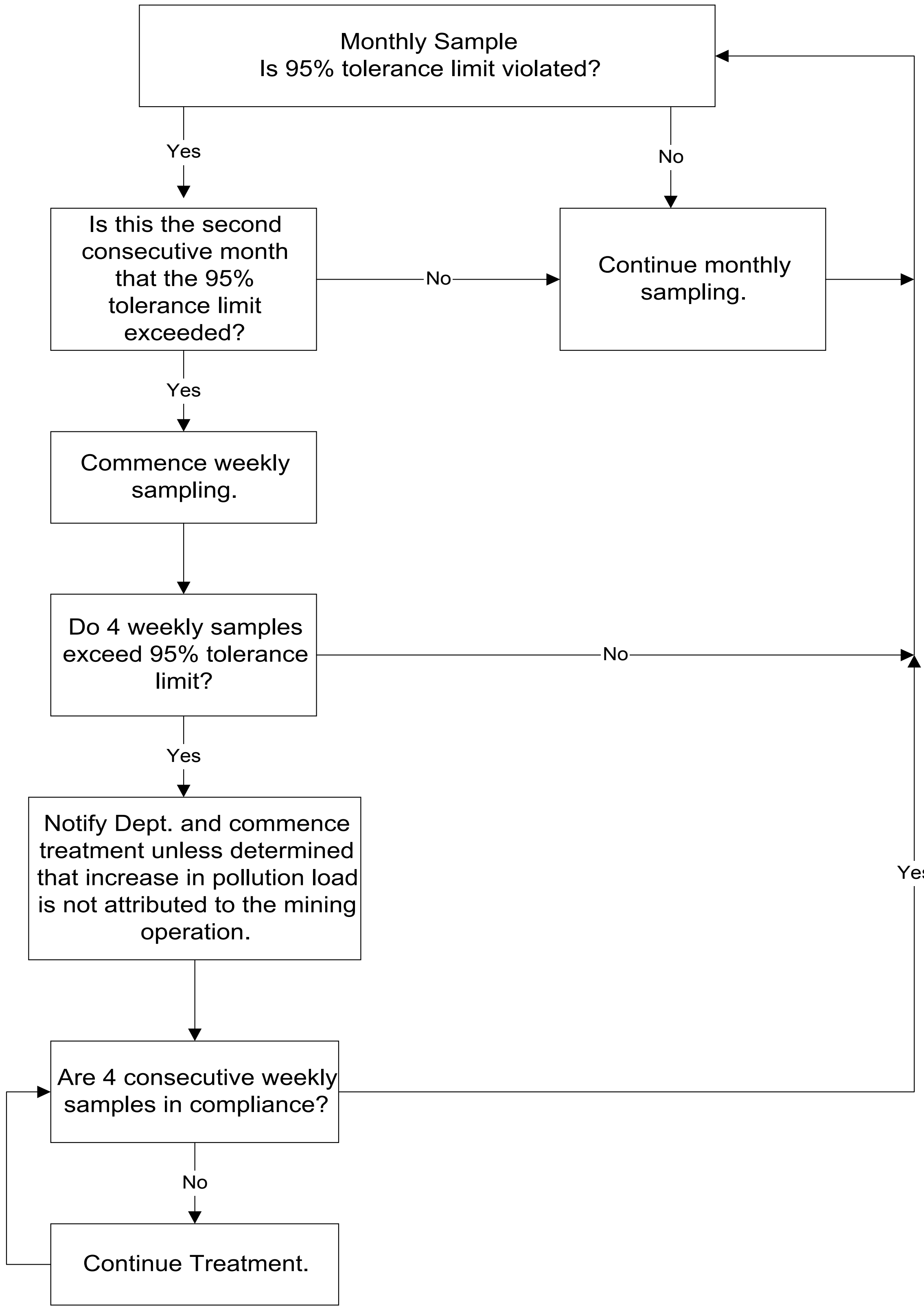
M = median, R = range between quartiles, and SQR(N) = the square root of the number of samples (McGill et. al., 1978).

An excursion (i.e., apparent violation) of the baseline pollution load occurs when the result of a sample analysis exceeds the 95 percent tolerance limit, or when a median of sample results obtained over a new water year is outside the bounds of the 95 percent confidence interval about the original baseline median. An excursion of the baseline pollution load above the 95 percent tolerance limit is known as a "quick trigger" violation. A more subtle and long-term trend of the pollution load above the 95 percent confidence interval about the median is known as a "subtle trigger" violation.

The 95 percent tolerance limit is determined by ranking the data in order of magnitude and dividing the data into 32 increments. The 95 percent tolerance limits correspond to the lowest and highest of the 32 increments. For datasets containing 16 or fewer samples, the approximate 95 percent tolerance limits correspond to the smallest and largest sample values. The upper 95 percent tolerance limit is the "quick trigger" or "critical" value mechanism for monthly monitoring data. If two consecutive monthly samples exceed the upper 95 percent tolerance limit, weekly monitoring is initiated. The quick trigger values are provided in the Surface Mine Permit. Permit conditions specify quick trigger monitoring and compliance steps shown in Figure 1.2b.

Determination of long-term compliance with the subtle trigger typically involves comparison of the pollution loading data for successive water years to the 95 percent confidence limit about the median for the baseline. The 95 percent confidence limits are also based on baseline data (Table 1.2a) and given in the Surface Mine Permit. The 95 percent confidence interval is defined as the range of values around the median in which the true population median occurs with a 95 percent probability. This value is used to determine if statistically significant changes in median pollution loads have occurred between the baseline monitoring period and water years during mining and postmining. Permit conditions specify the process that will be used to determine compliance with the subtle trigger.

Figure 1.2b: The Quick-Trigger Process



Box plots can be used to easily compare the baseline pollution load (or concentration) for different analytes to successive water-year datasets. Box plots can be constructed to show the median value, the 95 percent confidence limits around the median and the upper and lower quartiles and range of data. The length of the box corresponds to the interquartile range (IQR) equal to the 75th percentile minus the 25th percentile. Therefore, 50 percent of the data will fall within the range given by the length of the box. The upper whisker (the t-shaped line above the upper end of the boxes) extends to the largest value less than or equal to the 75^{th} percentile plus 1.5 times the IQR. Likewise, the lower whisker extends to the smallest value greater than or equal to the 25^{th} percentile minus 1.5 times the IQR. Any value that is beyond the whiskers is known as an extreme value. Extreme values less than 1.5 IQRs away from the nearer whisker (or equivalently, less than 3 IQRs away from the edge of the box) are represented by an open circle. Extreme values beyond 1.5 IQRs away from the nearer whisker are represented by an "x".

Figures 1.2c and 1.2d are examples of box plots of water quality data from the Dunkard Creek in Greene County, Pennsylvania (this acid mine drainage impacted stream segment is featured in several other figures in Section 2.0). Figure 1.2c shows variations in the range, median and quartiles of pH distributions for three time periods corresponding to significant changes in mining regulation and acid mine drainage (AMD) control and abatement in Pennsylvania. The box plot of pH data from 1950 to 1965 represents all available data (N=54) at this monitoring point prior to the Pennsylvania Clean Streams Law requiring that active mines treat acid mine drainage. This law went into effect in 1966. The box plot of pH data from 1983 to 1997 (N=175) represents the time period following the approval of Pennsylvania for primacy to regulate the Federal SMCRA of 1977. Primacy provided for significant increases in staff and resources for permitting, inspection and enforcement of active mine sites, and funds to reclaim abandoned mine sites with AMD problems. The median pH of 6.9 for the data (N=112) for the intermediate time period (1966-1982) is significantly different than the median pH of 3.95 for the time period prior to the 1966 AMD treatment requirement. Figure 1.2d shows box plots of manganese concentrations for the same monitoring point and same time periods as Figure 1.2c. The median and interquartile range for the 1966-1982 data (N=107) is significantly less than that of the 1950-1965 data (N = 14); and the range of the manganese concentrations in the 1983-1997 data (N = 173) is less than half of the range for the two previous time periods. Additional examples of box plots and explanations of their origin and development are contained in Tukey (1977), McGill, Tukey, and Larsen (1978), Veleman and Hoaglin (1981) and Helsel (1989).

Figure 1.2c: Dunkard Creek pH

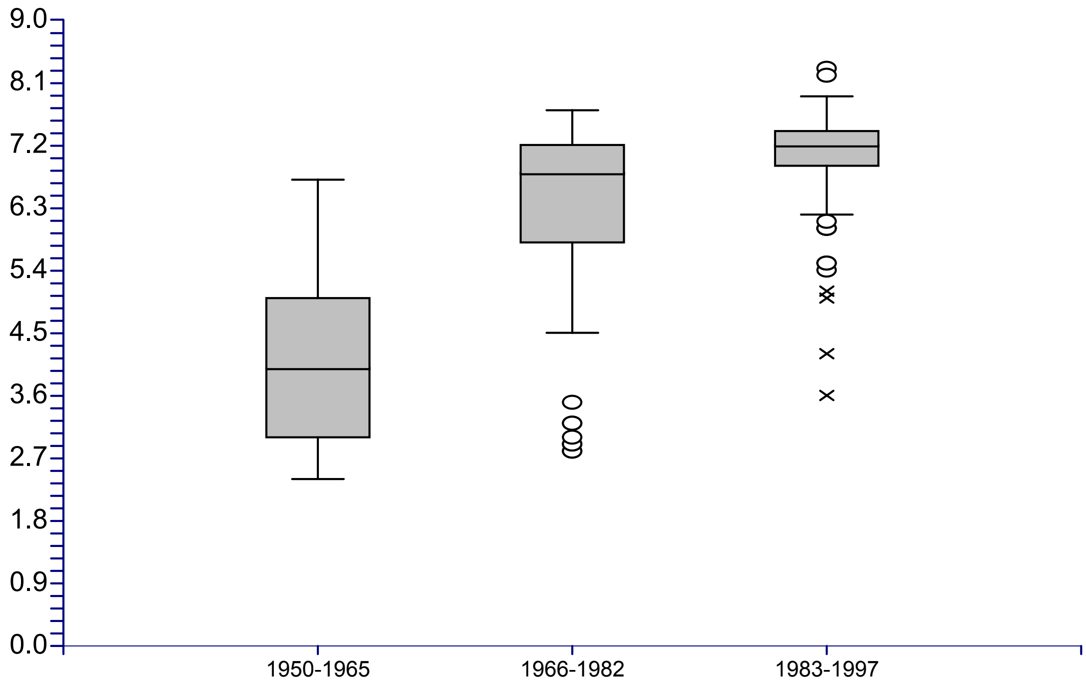
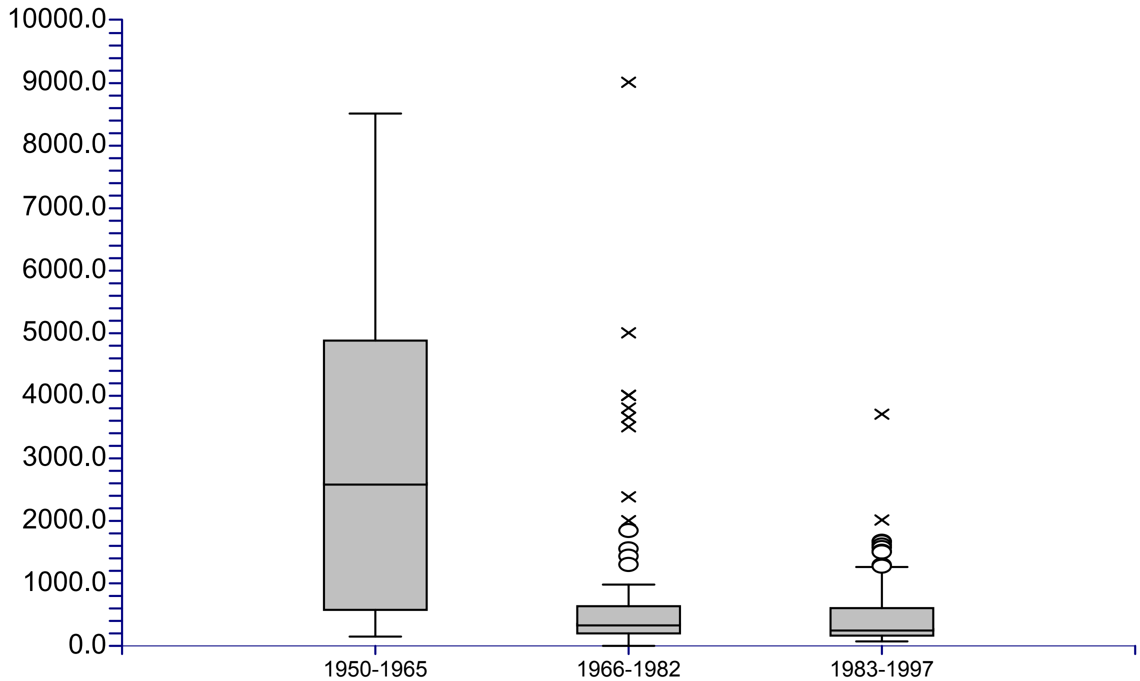


Figure 1.2d: Dunkard Creek Manganese (mg/L)



Monitoring and compliance inspections are conducted periodically (i.e., quarterly). Reviews of the monthly monitoring data for the purpose of comparing current data to the baseline data, checking for subtle and quick trigger violations, and noting any data trends, are conducted annually.

1.3 IMCC Evaluation of State Remining Programs

The Interstate Mining Compact Commission (IMCC) is a multi-state governmental organization representing the natural resource and environmental protection interests of its member states, including extensive interaction with EPA, OSMRE, and other federal agencies. The IMCC organized a national remining task force in 1996, with representation from EPA, OSMRE and member states, in order to develop and promote various remining incentives that would accomplish significant abandoned mine land reclamation and associated water quality benefits. A product of the IMCC Remining Task Force is a discussion paper on water quality issues related to coal remining, for which EPA, OSMRE, and IMCC jointly solicited comments in February 1998 from a wide range of environmental, industry, and government agency commentors/respondents.

In a related effort that is part of a cooperative project with EPA and OSMRE, the IMCC solicited and compiled responses from 20 states on their remining program experiences. This compilation of responses provides extensive information on the number of Rahall-type remining permits issued in the states, the contents of these permits (including the availability of baseline pollution load analyses and data), and the types and effectiveness of BMPs employed during remining operations. A summary of these responses is included as Appendix C of EPA's Coal Remining BMP Guidance Manual. IMCC also submitted 61 data packages to EPA from 6 member states. These data packages include pre-, during, and post-mining water quality data, BMP implementation plans, remining operation plans, geology and overburden analysis data, abandoned mine land conditions, and topographic maps.

Based upon review of the IMCC solicitation responses, 61 data packages, and discussions with state agency representatives, it is evident that baseline pollution load data requirements vary widely from state to state. Pennsylvania, Virginia and some other states generally require a minimum of 12 monthly samples of pre-existing pollutional discharges to calculate the baseline pollution load and characterize seasonal variations throughout the water year. One state water quality agency has advocated the use of 52 weekly samples to characterize baseline pollution load, which may have been a disincentive to remining. That state has only been able to issue a handful of Rahall remining permits. At the other end of the scale, another state has developed a draft sampling protocol to establish baseline pollution load with only 6 monthly samples, similar to the background sampling requirement for determining "probable hydrologic consequences" in most state surface mining permits. The draft protocol divides the water year into high-flow, low-flow, and intermediate-flow periods, and contains requirements for sampling each of these periods and considering transition periods and other hydrologic factors.

The establishment of the baseline pollution load is largely a statistical exercise because many pre-existing discharges are known to be highly variable in flow and/or water quality. The use of statistics is necessary to quantify these variations and to summarize the behavior of the discharges, which may be related to seasonal variations or other hydrologic factors. Statistical analysis of the baseline pollution load data also enables a distinction to be made, after remining has commenced, between normal seasonal variations and mining-induced changes in pollution load that will require initiation of treatment.

The baseline must consist of an adequate number of samples of sufficient intervals and duration, in order to provide adequate protection for both the industry and the regulatory authority against false triggers. The greater the number of samples and range of hydrologic conditions represented by the baseline pollution load determination, the greater the likelihood that the baseline pollution load determination is statistically and hydrologically sound. In attempting to establish the baseline pollution load with a relatively small number of samples, there is an inherent risk of under representation. In establishing national standards or guidelines for baseline pollution load, careful consideration must be given to determining the optimum number of samples, the associated time intervals, and sampling duration in order to achieve statistical and hydrologic credibility, without being overly burdensome, costly, or impractical.

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